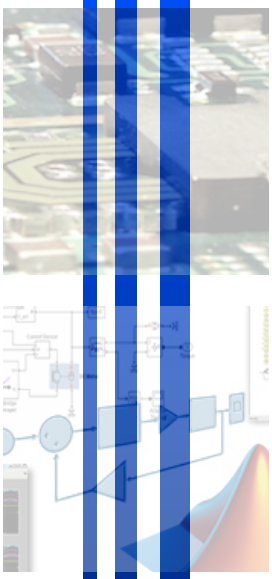
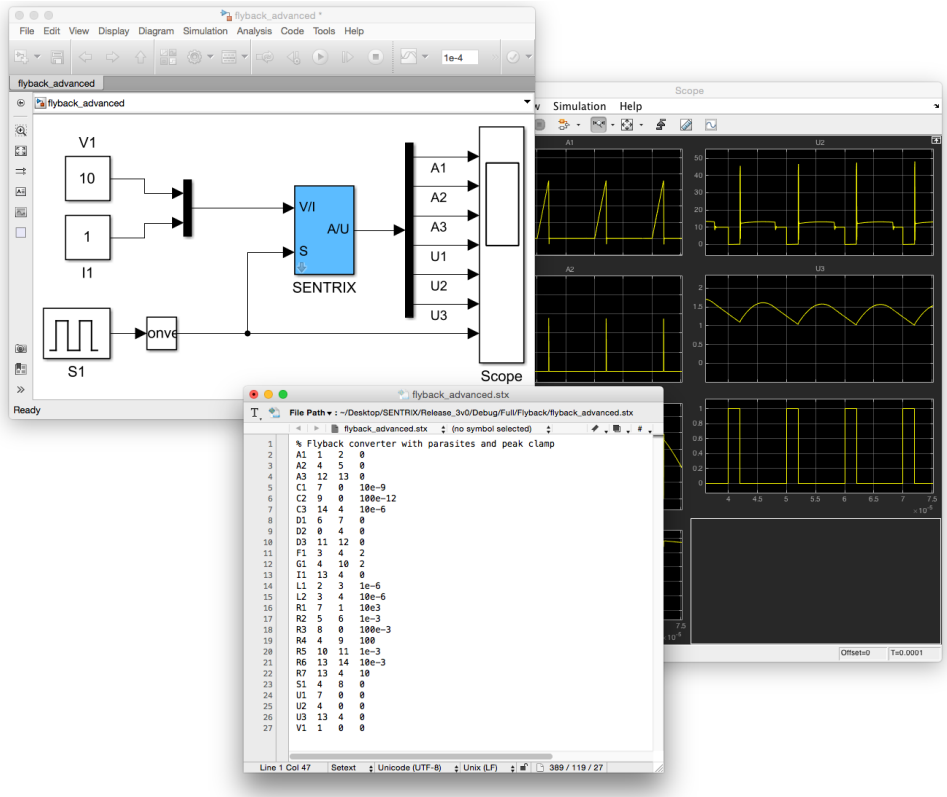


SENTRIX

User Manual



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1. Introduction to SENTRIX

In Simulink, control and other algorithm development for power converters requires some kind of representation (model) for the converter.

A first approach is to define a behavioural model that more or less mimics the actual electrical behaviour of the converter. Such a behavioural model generally allows fast simulation. However, the development process can be tedious and the model, although fast, is limited in accuracy. In another approach an electrical network of the power converter is translated into an abstract mathematical model. All electrical components, including parasites, can be taken into account. These models are rather difficult to create for each individual power converter. In general the electrical network models are far more accurate than the behavioural models but slow down the simulation speed tremendously. Modelling becomes even more cumbersome when the electrical network contains diodes. The state of a diode, conducting or non-conducting, and the precise moment of switching is not predictable a priori since the state depends on the internal network instantaneous currents and voltages. Furthermore electrical engineers prefer an electrical network representation instead of a behavioural block diagram or abstract mathematical equations.

SENTRIX® is a level-2 MATLAB S-function that overcomes these hurdles. The applied algorithm interprets a text file containing an electrical netlist representing the power converter to be simulated. The represented power converter gets integrated into the Simulink model seamlessly. Accurate switching of diodes is handled efficiently without undesired loss of simulation speed.

SENTRIX® is available at www.zeonpowertec.com

1.1. Features

- seamless integration into Simulink[1] and flawless operation in conjunction with the many available library components and toolboxes
- MAC-OS and Windows operating systems[2] are supported
- ease of installation with small software footprint
- basic electrical components - ideal inductors, ideal capacitors and resistors - are included and support initial condition setting where relevant
- ideal switches and diodes incorporate very fast transient calculation
- ideal transformers with adjustable transfer ratio can be applied
- meters support the measurement of any current or voltage inside the electrical network
- a simple ASCII netlist representation allows editing with any preferred commercially available editor
- multiple electrical networks can be instantiated in a single Simulink model

1.2. Installation

Extract the sentrix.zip file into a directory/folder of preference. Add the new directory/ folder to the MATLAB path or execute the simulation directly from the chosen directory/folder[3].

1.3. License information

A demo and a full version are available. The demo version is restricted in the number of nodes (5) and components (7) in the electrical network. Current sources cannot be applied in this version. The demo version is valid for a period of at maximum 190 days. The full version has no restrictions and has a validity of one year.

Entering *'sentrix'* at the MATLAB command prompt reports the current status of the license.

---

[1] *For MATLAB R2011a (version 7.12) and later versions*

[2] *Linux is not formally supported*

[3] *The sentrix.p file must be 'visible' for Simulink by being in the work directory/folder or search path*

2. Using the model

A Simulink model can contain multiple instantiations of various SENTRIX electrical networks. All these networks call the 'sentrix.p' level-2 MATLAB S-function. The respective netlists per block are imported in the simulator and used by the Simulink solver. The following example will demonstrate the usage.

2.1. Buck converter example

Fig. 1 shows a Simulink model containing a SENTRIX electrical network representation of a synchronous buck converter and its corresponding netlist.

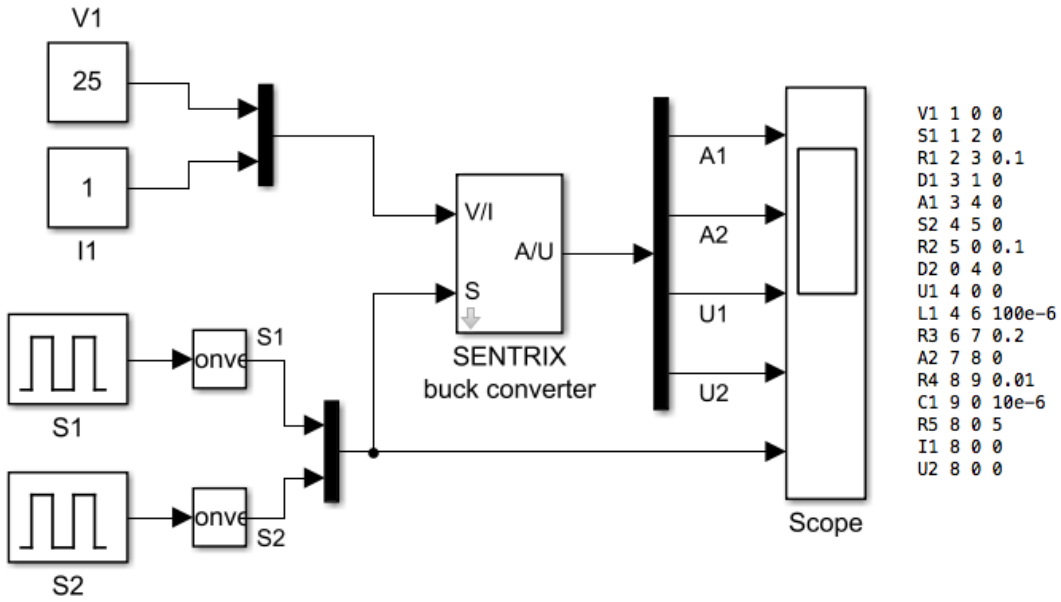

Fig. 1 Simulink model containing a SENTRIX electrical network representation of a buck converter with corresponding netlist

2.2. Block masks

The actual electrical network is masked for convenience. Fig. 2 shows the top level mask. The 'Open file…' button will pop-up a window for selection of the relevant netlist file. The extension of the netlist file has to be '.stx'. Alternatively a string containing the file name including absolute or relative path can be edited directly in the upper edit box. The lower edit box contains a vector with the initial condition settings for all capacitor voltages and inductor currents in the network. The order of appearance is the following: first all capacitor voltages and then all inductor currents in numerical ascending order (e.g. VC1, VC2, VC3, IL1, IL2, …).

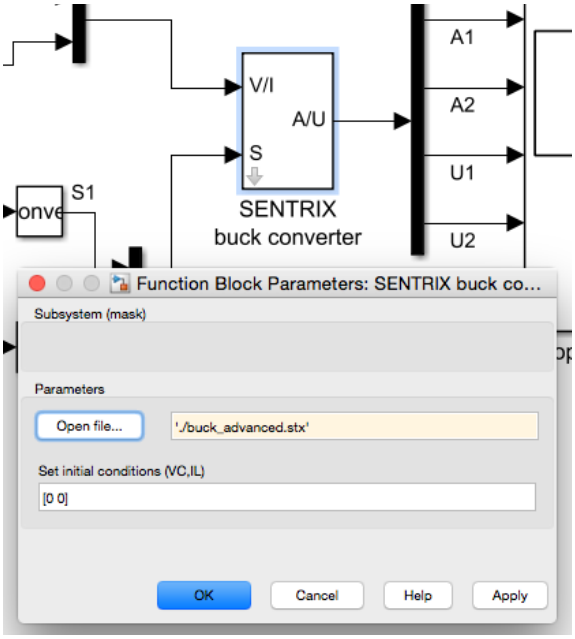

Fig. 2 Mask of the SENTRIX block

Underneath this top level mask the actual SENTRIX Electrical Network resides. This next level including mask is shown in Fig. 3. The top level mask entries for the netlist and initial conditions are automatically copied into the lower level mask.

As mentioned, the top level mask is for convenience only and might be deleted such that the lower level SENTRIX Electrical Network mask becomes available at top level.

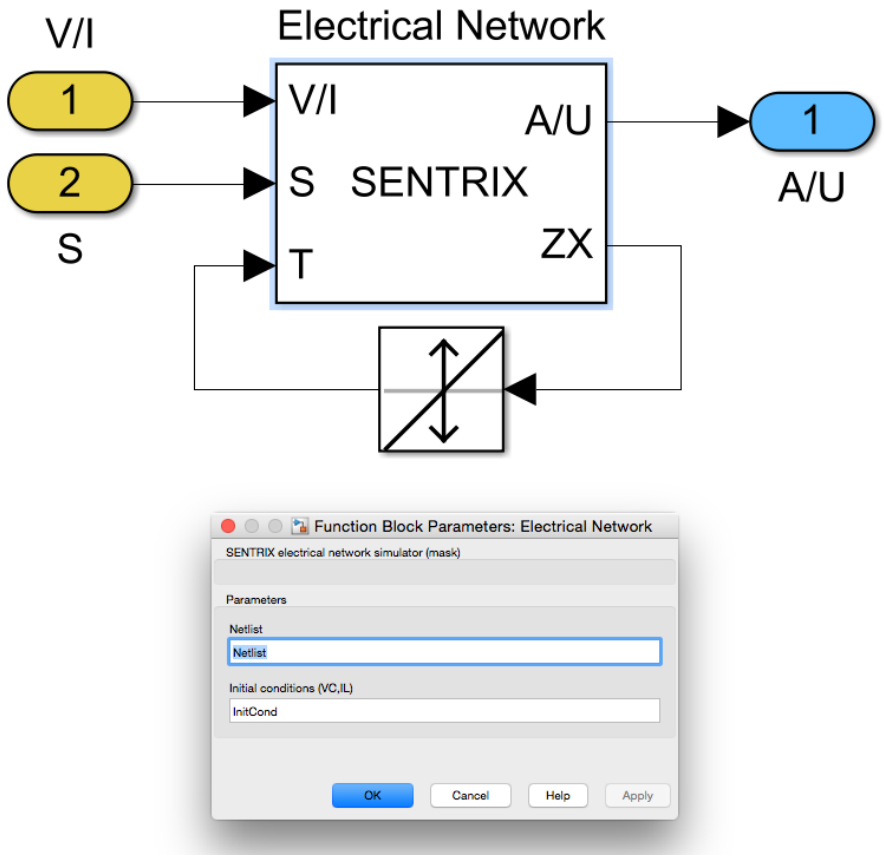

Fig. 3 SENTRIX Electric Network including mask

The SENTRIX Electrical Network calls the actual level-2 MATLAB S-function 'sentrix.p' during execution using the desired netlist ('Netlist') and initial conditions ('InitCond').

A HitCross[4] block must be connected between output ZX and input T. In this HitCross block detection should be in either direction, offset equals zero and the output port must be shown.

[4] *HitCross is a standard part of the Simulink library*

2.3. Block ports

Tab. 1 gives an overview of the available model ports of the SENTRIX Electrical Network. Each port is a multi-dimensional vector, depending on the amount of components per type. Any suitable source from the Simulink library can be connected to the input sources port. The output meters port can be connected to any suitable sink from the Simulink library.

Tab. 1 SENTRIX Electrical Network ports

Port	Description	Remark
V/I	input sources	voltage before current sources in ascending order (e.g. V1, V2, V3, I1, I2, …)
S	switches	ascending order (e.g. S1, S2, …), leave open when no switches are present in the electrical network
A/U	output meters	current before voltage meters in ascending order (e.g. A1, A2, A3, U1, U2, …)
ZX	zero-crossing detector	connect to the input of a standard Simulink HitCross block - this block is always required to be present with detection in either direction, offset zero and output port shown
T	trigger input	connect to the input of a standard Simulink HitCross block - this block is always required to be present with detection in either direction, offset zero and output port shown

2.4. Netlist conventions

The netlist describing the electrical network has to comply with several format rules. An example netlist is shown in Fig. 4.

Netlist format rules:

- the netlist is a standard text file in ASCII format
- the netlist file extension is '.stx'
- the first line is a compulsory header line containing arbitrary information
- subsequent lines describe the electrical network, one line per component
- a line has the format: 'component type', 'positive node', 'negative node' 'component value' - Tab. 2 gives an overview of the various components
- on each line the type, nodes and value are separated by a space or a tab
- the node numbers need to be positive integers
- all components require values - see Tab. 2
- 'NaN' and 'Inf' are not allowed as component value
- the components can be in arbitrary order
- at least one capacitor or inductor should be included in the netlist
- at least one source, either current or voltage, should be included in the netlist
- at least one meter, either current or voltage, should be included in the netlist

```
% Forward converter
V1  1 0 0
S1  1 2 0
D1  0 2 0
S2  4 0 0
D2  4 1 0
U1  2 0 0
L1  2 3 100e-6
A1  3 4 0
R1  2 4 1e6
F1  4 2 0.5
G1  4 5 0.5
D3  5 6 0
D4  4 6 0
U2  6 4 0
A2  6 7 0
L2  7 8 1e-3
C1  8 4 10e-6
R2  8 4 10
I1  8 4 0
U3  8 4 0
```

Fig. 4 Example SENTRIX netlist

Tab. 2 Netlist components

Comp. type	Description	Positive node	Negative node	Comp. value	Remark
A	current meter	current in	current out	0	
C	ideal capacitor	positive terminal	negative terminal	capacitor value	initial condition set via mask
D	ideal diode	anode	cathode	0	
F	ideal transformer primary	positive terminal	negative terminal	transfer ratio - primary/ secondary turns	a F_x value (N_{prim}/N_{sec}) has to be equal to the corresponding G_x value, so F1=G1, F2=G2, … value
G	ideal transformer secondary	positive terminal	negative terminal	transfer ratio - primary/ secondary turns	a G_x value (N_{prim}/N_{sec}) has to be equal to the corresponding F_x value, so G1=F1, G2=F2, … value
I	current source	current in	current out	0	actual value set in Simulink top level model via the first input port
S	ideal switch	current in	current out	0	control of the switch is via boolean logic ('0' = open, '1' = short) and set in the Simulink top level model via the second input port
L	ideal inductor	current in	current out	inductor value	initial condition set via mask
U	voltage meter	positive terminal	negative termal	0	
V	voltage source	positive terminal	negative termal	0	actual value set in Simulink top level model via the first input port

3. Error messages

SENTRIX incorporates a limited amount of error checking. Tab. 3 gives an overview of the error messages and the probable causes. These error checks exist next to the common Simulink error checks and can be traced back in the Simulink Diagnostic Viewer.

3.1. Error categories

The various error messages are categorised into license, netlist, simulation and demo version related. The demo version errors do not apply to the full version. License information when a license error occurs can be retrieved by entering *'sentrix'* at the command prompt. The actual license information will be displayed. Netlist errors prevent the simulation from starting execution, whereas simulation related errors can occur during the simulation.

3.2. State dependence

SENTRIX applies ideal components for switches and diodes. Depending on the netlist and network configuration this can result in a dependence between capacitor voltages or inductor currents and sources or between sources directly. Examples are:

- shorted capacitors
- shorted voltage sources
- open inductors
- open current sources
- capacitors in parallel to voltage sources
- inductors in series with current sources
- parallel voltage sources
- series current sources

These cases are illegal since in the ideal case they would result in infinite currents or voltages. The SENTRIX algorithm however will immediately try to change to a more appropriate topology by turning on/off diodes present in the network and ensure that the Simulink solver can continue the simulation without issuing an error.

In a practical non-ideal case these state dependences would never actually occur since there is always (parasitic) impedance involved that limits the currents and voltages. So as a solution when SENTRIX issues error E201 (see Tab. 3) the netlist can be changed by adding resistance(s) to the network such that the state dependence is removed.

Tab. 3 Error messages

Code	Description	Cause
License related		
E000	No valid SENTRIX license for this computer	A license is coupled to MAC-addresses. The MAC-address of the current computer is not in the license list.
E001	License expired - visit www.zeonpowertec.com for license renewal	The license has expired and has to be renewed
Netlist related		
E100	Netlist file does not exist	Either the path (absolute or relative) or file name doesn't exist
E101	Netlist file requires ''.stx'' extension	The file doesn't have the required '.stx' extension
E102	Unidentified component in netlist	A component other than defined in Tab. 2 has been used
E103	At least one capacitor or inductor has to be present in the network	Neither a single capacitor or inductor has been used in the network
E104	At least one source has to be present in the network	No source has been used in the network
E105	At least one meter has to be present in the network	No meter has been used in the network
E106	Double component entries in netlist	The same component is used multiple times
E107	Component values should not be 'Inf' or 'NaN'	Only numerical component values are allowed
E108	Only positive integers allowed for node numbering	A negative or non-integer node reference is made in the netlist
E109	Wrong transformer dimensioning	Corresponding transformer transfer ratios do not match
E110	Node error in netlist	A node number has been skipped from the netlist

Code	Description	Cause
Simulation related		
E200	Wrong number of initial conditions set	The number of initial conditions set does not match the actual number of capacitors and inductors in the netlist
E201	State dependence	See section 3.2
E202	No solution found	During simulation the solver encounters an unsolvable network configuration
E203	Conflicting initial conditions	The initial conditions are chosen such that the solver finds no suitable network configuration
Demo version related		
E300	Maximum number of demo version nodes (5) or components (7) reached	Too many nodes or components are used
E301	No current source allowed in the demo version	Current sources are not to be used

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